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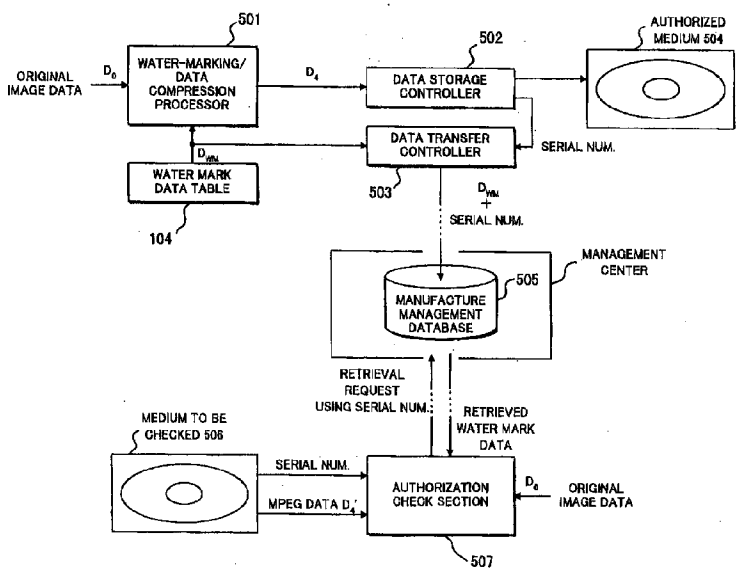
(54) Electronic watermark system

(57) An electronic watermark system invisibly embeds watermark information into original image data and the watermarked image data is transferred to a first medium (504, 604). At the same time, the embedded watermark information is transferred to a second medium (505, 605). When a medium questioned is found, its watermark information can be easily identified by searching the second medium. Alternatively, the watermarked image data and the embedded watermark information are transferred to different storage areas (705, 706) of the same medium (704), respectively.

FIG. 5



EP 0 859 503 A2

Description

The present invention generally relates to an authorization system, and in particular to an authorization system using identification information embedded into image data to prevent unauthorized duplication of the image data.

Recently, unauthorized copying of digital image data has become a serious problem because duplication of digital data can be extremely easy. To prevent unauthorized copying, several authorization systems using identification information (an electronic watermark) embedded into image data have been proposed

A visible-watermarking system is disclosed in Japanese Patent Unexamined Publication No. 8-241403 which corresponds to United States Patent No. 5,530,759. In this system, a visible watermark is placed on a digital image such that the corresponding pixel of original image changes its brightness but its chromaticities.

An invisible-watermarking system is disclosed in NIKKEI ELECTRONICS 1996.4.22 (no. 660). In this system, original image data is converted into frequency spectrum and then ID information is embedded into the frequency spectrum which is in turn converted into image data invisibly including the ID information. In authorization check, image data questioned is converted into frequency spectrum. ID information embedded in the image data questioned is obtained from a difference between the frequency spectrum questioned and the original frequency spectrum. Since the ID information is embedded into frequency spectrum of the original image data, it has little effect on the image quality and further it has become very difficult to delete the ID information from the image data.

In the above invisible-watermarking system, since the ID information cannot be seen, it is difficult to check whether image data is authorized in the case where no one knows the ID information. Especially, in a distribution system of data storing medium including CD-ROMs, there are cases where a different watermark is used for each distribution channel. In this case, the authorization check and manufacture management become very complicated and time-consuming jobs.

All object of the present invention is to provide a system which can rapidly check whether image data is authorized to effectively prevent unauthorized copying of the image data.

Another object of the present invention is to provide a system which can easily identify an electronic watermark invisibly embedded in image data to check whether the image data is authorized.

According to an aspect of the present invention, watermarked image data having watermark information invisibly embedded is transferred to a first medium and the embedded watermark information is transferred to a second medium. Since the embedded watermark information is stored in the second medium, watermark identification can be easily made.

Further, in an authorization check system for checking whether a medium questioned is authorized, a storage stores watermark information and medium identification information identifying a medium, the medium storing watermarked image data which is produced by invisibly embedding the watermark information into original image data. A retrieval controller retrieves watermark information corresponding to medium identification Information of the medium questioned from the storage. A watermark extractor extracts watermark information questioned from image data stored in the medium questioned. A checker checks whether the medium questioned is authorized by comparing the extracted watermark information with the retrieved watermark information.

According to another aspect of the present invention, watermarked image data having watermark information invisibly embedded and the embedded watermark information are both transferred to a single medium. Preferably, the embedded watermark information may be stored in a dedicated storage area of the single medium. Further, the embedded watermark information may be encrypted and stored. Since the embedded watermark information is stored in the same medium, watermark identification can be easily made.

Further, in an authorization check system for checking whether a medium questioned is authorized, the medium questioned having a first storage area for storing watermarked image data and a second storage area for storing watermark information. After extracting watermark information from image data stored in the medium questioned, a checker checks whether the medium questioned is authorized by comparing the extracted watermark information with the watermark information stored in the second storage area of the medium questioned.

Fig. 1 is a schematic block diagram showing an encoding side of an electronic watermark system according to the present invention;

Fig. 2 is a schematic block diagram showing a watermark check section of the electronic watermark system according to the present invention;

Fig. 3 is a schematic diagram showing an example of watermarking section of the encoding side of Fig. 1;

Fig. 4 is a schematic diagram showing an example of a watermark extractor of the watermark check section of Fig. 2;

Fig. 5 is a diagram showing a first embodiment of an electronic watermark system according to the present invention;

Fig. 6 is a diagram showing an electronic watermark system according to a second embodiment of the present invention;

Fig. 7A is a schematic diagram showing an encoding side of an electronic watermark system according to a third embodiment of the present invention; and

Fig. 7B is a schematic diagram showing a decoding side of the electronic watermark system according to the third embodiment.

ENCODING SIDE

Referring to Fig. 1, an encoding side of an electronic watermark system inputs a stream of original image data D_0 and produces both MPEG (Motion Picture Experts Group) data stream D_4 and watermark data which is invisibly embedded into the MPEG data D_4. More specifically, a stream input section 101 inputs a stream of the original image data which is converted to frequency spectrum data D_1 by a DCT (Discrete Cosine Transform) section 102. A watermarking section 103 reads a watermark D_{WM} selected from a plurality of watermarks stored in a watermark data table 104, and then embeds the selected watermark D_{WM} into the frequency spectrum data D_1 to produce watermark-embedded frequency spectrum data D_2. The watermark-embedded frequency spectrum data D_2 is quantized by a quantizing section 105 and the quantized data D_3 is encoded to produce MPEG data by an encoding section 106. A transfer controller 107 inputs the MPEG data from the encoding section 106 to produce a stream of the MPEG data D_4 and a transfer controller 108 inputs the selected watermark D_{WM} from the watermark data table 104 to produce selected watermark data. The stream of the MPEG data D_4 is transferred to a storage medium or a client through a communication channel and the selected watermark data is transferred to another storage medium or the same storage medium, as will be described later.

It should be noted that the above sections 101-106 may be implemented with a program-controlled processor such as CPU or DSP. In other words, the processor runs programs including the functions of the above section 101-106 to perform the watermarking and MPEG data compression as described above.

WATERMARK CHECKING SECTION

Referring to Fig. 2, in a watermark checking section of the electronic watermark system, a stream data input section 201 inputs a stream of MPEG data D_4` and a watermark input section 202 inputs watermark data associated with the input MPEG data $D_4$`. The input MPEG data D_4` is decoded to produce date D_3' by a decoding section 203 and then the date D_3' is inverse-quantized to produce data D_2' by an inverse-quantizing section 204. On the other hand, the watermark checking section is provided with an original image memory 205 storing the original image data D_0. The original image date D_0 is converted to frequency spectrum data D_1 by a DCT section 206.

When receiving the input frequency spectrum data D_2' from the DCT section 204 and the original frequency spectrum data D_1 from the DCT section 206, a watermark extractor 207 extracts a watermark D_{WM1} from the input frequency spectrum data D_2' by calculating a difference between the input frequency spectrum data D_2' and the original frequency spectrum data D_1. An inner product calculating section 208 inputs the extracted watermark D_{WM1} from the watermark extractor 207 and the received watermark D_{WM2} from the watermark input section 202, and performs the inner product thereof to produce a degree of statistical similarity between them. An authorization check section 209 checks whether the extracted watermark D_{WM1} is identical to the received watermark D_{WM2} by comparing the degree of statistical similarity with a reference value.

The input MPEG data D_4' may be received from a storage medium or a communication network. The watermark data associated with the input MPEG data D_4' is received from a management database storing manufacture management data or the same storage medium as the MPEG data D_4`, as will be described later. In the case where the input MPEG data D_4' and/or the watermark data are received from a communication network, the watermark checking section is provided with a communication means such as a network interface or a radio transceiver.

It should be noted that the above sections 201-209 may be implemented with a program-controlled processor such as CPU or DSP. In other words, the processor runs programs including the functions of the above section 201-209 to perform the watermark extracting, MPEG data decompression and authorization check as described above.

WATERMARKING

Referring to Fig. 3, the watermarking section 103 receives the frequency spectrum data D_1 from DCT section 102 and selects a set of N data samples: f(1)-f(n) which are greater than a predetermined threshold level from the frequency spectrum data D_1. Further, the watermarking section 103 selects a set of watermark data: w(1)-w(n) from random numbers depending on a normal distribution with a mean of 0 and a variance of 1. The watermarking section 103 calculates $F(i) = f(i) + \alpha|f(i)|^*w(i)$ for each variable i ($1 \leqq i \leqq n$) using multipliers 301 and 302, a constant α and an adder 303, where α is a scaling element (hereinafter, assuming $\alpha = 1$). The calculated data samples F(1)-F(n) are substituted for the selected N data samples f(1)-f(n) of the frequency spectrum data D_1 to produce water-

marked DCT frequency spectrum data which will be subject to inverse DCT in the following stage 105. In this manner, the selected watermark D_{WM} is invisibly embedded into the original image data D_0.

WATERMARK CHECK

Referring to Fig. 4, the watermark extractor 207 inputs the received data samples F(1)-F(n) of the received frequency spectrum data D_2' and the original data samples f(1)-f(n) of the original frequency spectrum data D_1. The watermark extractor 207 calculates $w_1(i) = (F(i) - f(i)) / f(i)$ for each variable i ($1 \leqq i \leqq n$) using subtracter 401 and a divider 402 to extract the watermark $D_{WM1} = (w_1(1), w_1(2), \cdots, w_1(n))$.

Subsequently, the inner product calculating section 208 calculates a degree of statistical similarity C between the extracted watermark $D_{WM1} = (w_1(1), w_1(2), \cdots, w_1(n))$ and the received watermark $D_{WM2} = (w_2(1), w_2(2), \cdots, w_2(n))$ using the following equation: $C = D_{WM1} * D_{WM2} / |D_{WM1}| * |D_{WM2}|$. If C is equal to or greater than the predetermined level, it is determined that the received watermark is embedded into the received MPEG data D_4' and therefore the received MPEG data D_4' is the authorized data. If C is smaller than the predetermined level, it is determined that the received MPEG data D_4' is an unauthorized duplication.

FIRST EMBODIMENT

Referring to Fig. 5, the encoding side of the electronic watermark system is comprised of a processor 501, the watermark data table 104, a data storage controller 502 and a data transfer controller 503. As described before, the processor 501 runs programs including the functions of the sections 101-106 as shown in Fig. 1 to perform the watermarking and MPEG data compression.

The processor 501 inputs a stream of original image data D_0 and produces the water-marked MPEG data stream D_4 which is stored onto a storage medium 504 such as CD-ROM or magneto-optic disc by the data storage controller 502. At the same time, the data storage controller 502 outputs a serial number of the storage medium 504 to the data transfer controller 503. In this manner, an authorized medium 504 storing MPEG data stream D_4 into which the selected watermark data D_{WM} is embedded is manufactured. If the processor 501 selects another watermark data, an authorized medium 504 storing the same MPEG data stream D_4 into which a different watermark data is embedded is easily manufactured. Needless to say, the data storage controller 502 outputs the serial number of the storage medium 504 to the data transfer controller 503.

The data transfer controller 503 inputs the embedded watermark data D_{WM} from the watermark data table 104 and then transfers a pair of the embedded watermark data D_{WM} and the serial number of the storage medium 504 to a manufacture management database 505 provided in a management center. Therefore, the watermark for each authorized medium 504 can be easily identified by searching the manufacture management database 505. In the case where the management center is located at a distance from the encoding side, the data transfer controller 503 may transfer them through a local-area network or a radio communication channel.

When a suspect medium 506 is found, the authorization check is performed by an authorization check section 507 running the programs including the functions of the above sections 201-209 as shown in Fig. 2 to perform the watermark extracting, MPEG data decompression and authorization check. In this case, the authorization check section 507 includes data communication means.

First of all, the authorization check section 507 reads the serial number from the suspect medium 506 and transmits a retrieval request using the read serial number to the manufacture management database 505 through a network. Upon receipt of the retrieval request, the manufacture management database 505 is searched for the corresponding watermark to the serial number. If the corresponding watermark is found, the retrieved watermark data is sent back to the authorization check section 507.

Using the retrieved watermark data, the authorization check section 507 performs the watermark extracting and watermark checking operations as described before. That is, if the degree of statistical similarity C between the extracted watermark and the retrieved watermark is equal to or greater than the predetermined level, it is determined that the medium 506 is one of authorized media. If C is smaller than the predetermined level, it is determined that the medium 506 is an unauthorized duplication.

SECOND EMBODIMENT

Referring to Fig. 6, the encoding side of the electronic watermark system is comprised of a processor 601, the watermark data table 104, a data communication controller 602 and a data transfer controller 603. As described before, the processor 601 runs programs including the functions of the sections 101-106 as shown in Fig. 1 to perform the watermarking and MPEG data compression.

The processor 601 inputs a stream of original image data D_0 and produces the water-marked MPEG data stream D_4 which is transmitted to a client 604 by the data communication controller 602. Here, it is assumed that the water-marked MPEG data is distributed depending on a data transmission request received from the client 604. At the same time, the data communication controller 602 outputs the address number of the client 604 to the data transfer controller

603. In this manner, the MPEG data stream D_4 into which the selected watermark data D_{WM} is embedded is transmitted to the authorized client 604. If the data transmission request is received from another client, the processor 601 selects another watermark data which is embedded into the MPEG data The MPEG data stream D_4 into which a different watermark data is embedded is transmitted to the net client. Needless to say, the data storage controller 602 outputs the address number of that new client to the data transfer controller 603.

The data transfer controller 603 inputs the embedded watermark data D_{WM} from the watermark data table 104 and then transfers a pair of the embedded watermark data D_{WM} and the client address number to a manufacture management database 605 provided in a management center. Therefore, the watermark for each authorized client 604 can be easily identified by searching the manufacture management database 605. In the case where the management center is located at a distance from the encoding side, the data transfer controller 603 may transfer them through a local-area network or a radio communication channel. Further the management database 605 is provided with data communication controller 606.

When a suspect data provider 607 is found, the authorization check is performed by an authorization check section 608 running the programs including the functions of the above sections 201-209 as shown in Fig. 2 to perform the watermark extracting, MPEG data decompression and authorization check. In this case, the authorization check section 508 includes data communication means.

First of all, the authorization check section 608 receives the address number from the suspect data provider 607 and transmits a retrieval request using the address number to the manufacture management database 605 through the data communication controller 606. Upon receipt of the retrieval request, the manufacture management database 605 is searched for the corresponding watermark to the address number. If the corresponding watermark is found, the retrieved watermark data is sent back to the authorization check section 608.

Using the retrieved watermark data, the authorization check section 608 performs the watermark extracting and watermark checking operations as described before. That is, if the degree of statistical similarity C between the extracted watermark and the retrieved watermark is equal to or greater than the predetermined level, it is determined that the data provider 607 is one of authorized clients. If C is smaller than the predetermined level, it is determined that the data provider 607 distributes an unauthorized duplication.

THIRD EMBODIMENT

Referring to Fig. 7A, the encoding side of the electronic watermark system is comprised of a processor 701, the watermark data table 104, an encryption section 702 and a data storage controller 703. As described before, the processor 701 runs programs including the functions of the sections 101-106 as shown in Fig. 1 to perform the watermarking and MPEG data compression. Further, the processor 701 may include the encryption section 702 and the data storage controller 703.

The processor 701 inputs a stream of original image data D_0 and produces the water-marked MPEG data stream D_4 which is stored onto a storage medium 704 such as CD-ROM or magneto-optic disc by the data storage controller 703. At the same time, the encryption section 702 encrypts the selected watermark data D_{WM} and the encrypted watermark data is stored onto the same storage medium 704 by the data storage controller 703. It is preferably that the storage medium 704 has a first area 705 for storing the water-marked MPEG data and a second area 706 dedicated to the encrypted watermark data. In the case of MPEG data reading mode, no data can read from the second area 706.

In this manner, an authorized medium 704 storing the encrypted watermark data D_{WM} and the water-marked MPEG data stream D_4 is manufactured. If the processor 701 selects another watermark data, an authorized medium 704 storing the new watermark data and the same MPEG data stream D_4 into which the new watermark data is embedded is easily manufactured.

Referring to Fig. 7B, when a suspect medium 707 is found, the authorization check is performed by an authorization check section 708 running the programs including the functions of the above sections 201-209 as shown in Fig. 2 to perform the watermark extracting, MPEG data decompression and authorization check. In this case, the authorization check section 708 includes decryption section 709.

First off all, the decryption section 709 reads the watermark data from the second area dedicated to watermark of the suspect medium 707 and decrypts it to output watermark data D_{WM}' to the authorization check section 708. Using the read watermark data D_{WM}', the authorization check section 708 performs the watermark extracting and watermark checking operations as described before. That is, if the degree of statistical similarity C between the extracted watermark and the read watermark D_{WM}' is equal to or greater than the predetermined level, it is determined that the medium 707 is one of authorized media. If C is smaller than the predetermined level, it is determined that the medium 707 is an unauthorized duplication.

As described above, since the authorized watermark can be easily obtained from a management center or the storage medium storing the watermarked MPEG data, the authorization check is rapidly performed with reliability.

Claims

1. A system comprising

   an information generator (104) for generating watermark information; and
   a combiner (103) for invisibly embedding the watermark information into original image data to produce watermarked image data,
   characterized by comprising:
   a transfer controller (108, 109) for transferring the watermarked image data to a first medium and the watermark information to a second medium.

2. The system according to claim 1, wherein the transfer controller further transfers medium identification information identifying the first medium to the second medium to allow retrieval.

3. The system according to claim 1 or 2, wherein

   the first medium is a first storage medium (504) for storing the watermarked image data; and
   the second medium is a second storage medium (505) for storing the watermark information and medium identification information identifying the first storage medium to allow retrieval.

4. The system according to claim 3, wherein the medium identification information is a manufacture serial number of the first storage medium.

5. The system according to claim 1 or 2, wherein

   the first medium is a communication medium through which the watermarked image data is transmitted to a destination (604) in a communication network; and
   the second medium is a storage medium (605) for storing the watermark information and medium identification information identifying the destination to allow retrieval.

6. The system according to claim 5, wherein the medium identification information is an address of the destination in the communication network.

7. A system comprising:

   an information generator (104) for generating information; and
   a combiner (103) for invisibly embedding the watermark information into original image data to produce watermarked image data,
   characterize by comprising:
   a transfer controller (108, 109) for transferring both the watermarked image data and the watermark information to a single medium.

8. The system according to claim 7, wherein the single medium is a storage medium (704) having a first storage area (705) for storing the watermarked image data and a second storage area (706) for storing the watermark information, wherein the second storage area is dedicated to the watermark information so that only the watermark information is allowed to be read.

9. The system according to claim 7 or 8, wherein the transfer controller encrypts the watermark information and transfers encrypted watermark information to the single medium.

10. A system for checking whether a medium questioned is authorized, characterized by comprising:

    a storage (505, 605) for storing watermark information and medium identification information identifying a medium, the medium storing watermarked image data which is produced by invisibly embedding the watermark information into original image data;
    a retrieval controller (505, 605) for retrieving watermark information corresponding to medium identification information of the medium questioned from the storage;
    a watermark extractor (207) for extracting watermark information questioned from image data stored in the medium questioned; and
    a checker (208, 209) for checking whether the medium questioned is authorized by comparing the extracted watermark information with the retrieved watermark information.

11. A system for checking whether a medium questioned is authorized, the medium questioned having a first storage area for storing watermarked image data and a second storage area for storing watermark information, the system characterized by comprising:

    a watermark extractor (207) for extracting watermark information from image data stored in the medium questioned; and
    a checker (208, 209) for checking whether the medium questioned is authorized by comparing the extracted watermark information with the watermark information stored in the second storage area of the medium questioned.

12. A method for checking whether a medium questioned is authorized, comprising the steps of:

    generating watermark information: and

invisibly embedding the watermark information into original image data to produce watermarked image data,

characterized by the steps of:

transferring the watermarked image data to an authorized medium;

transferring the watermark information and medium identification information identifying the authorized medium to a retrieval medium;

retrieving watermark information corresponding to medium identification information of the medium questioned from the retrieval medium;

extracting watermark information questioned from image data stored in the medium questioned: and

checking whether the medium questioned is authorized by comparing the extracted watermark information with the retrieved watermark information.

13. A method for checking whether image data questioned is authorized, comprising the steps of:

generating watermark information; and

invisibly embedding the watermark information into original image data to produce watermarked image data,

characterized by the steps of:

transmitting the watermarked image data to an authorized destination through a network;

transferring the watermark information and medium identification information identifying the authorized destination to a retrieval medium;

retrieving watermark information corresponding to identification information of a data provider providing the image data questioned from the retrieval medium;

extracting watermark information from the image data questioned received from the data provider; and

checking whether the image data questioned is authorized by comparing the extracted watermark information with the retrieved watermark information.

14. A method for checking whether a medium questioned is authorized, comprising the steps of:

generating watermark information; and

invisibly embedding the watermark information into original image data to produce watermarked image data,

characterized by the steps of:

transferring both the watermarked image data and the watermark information to an authorized medium;

extracting watermark information from image data stored in the medium questioned; and

checking whether the medium questioned is authorized by comparing the extracted watermark information with watermark information stored in the medium questioned.

FIG. 1

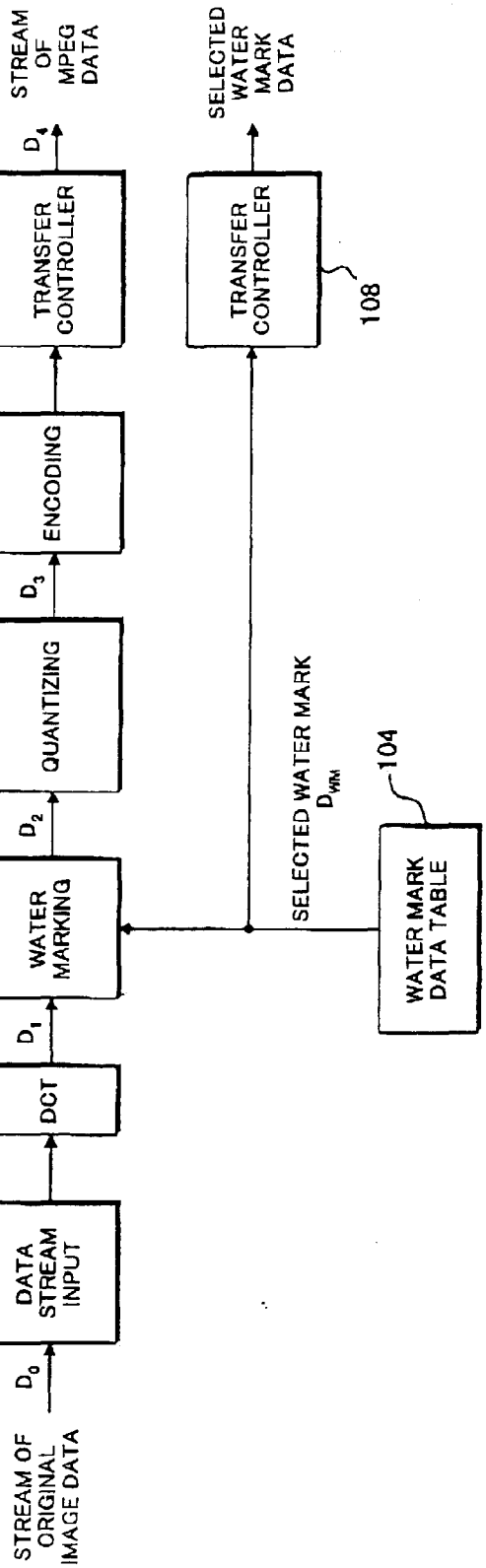

STREAM OF ORIGINAL IMAGE DATA
D_0
101
DATA STREAM INPUT
102
DCT
D_1
103
WATER MARKING
D_2
105
QUANTIZING
D_3
106
ENCODING
107
TRANSFER CONTROLLER
D_4
STREAM OF MPEG DATA
SELECTED WATER MARK D_{WM}
104
WATER MARK DATA TABLE
108
TRANSFER CONTROLLER
SELECTED WATER MARK DATA

FIG. 2

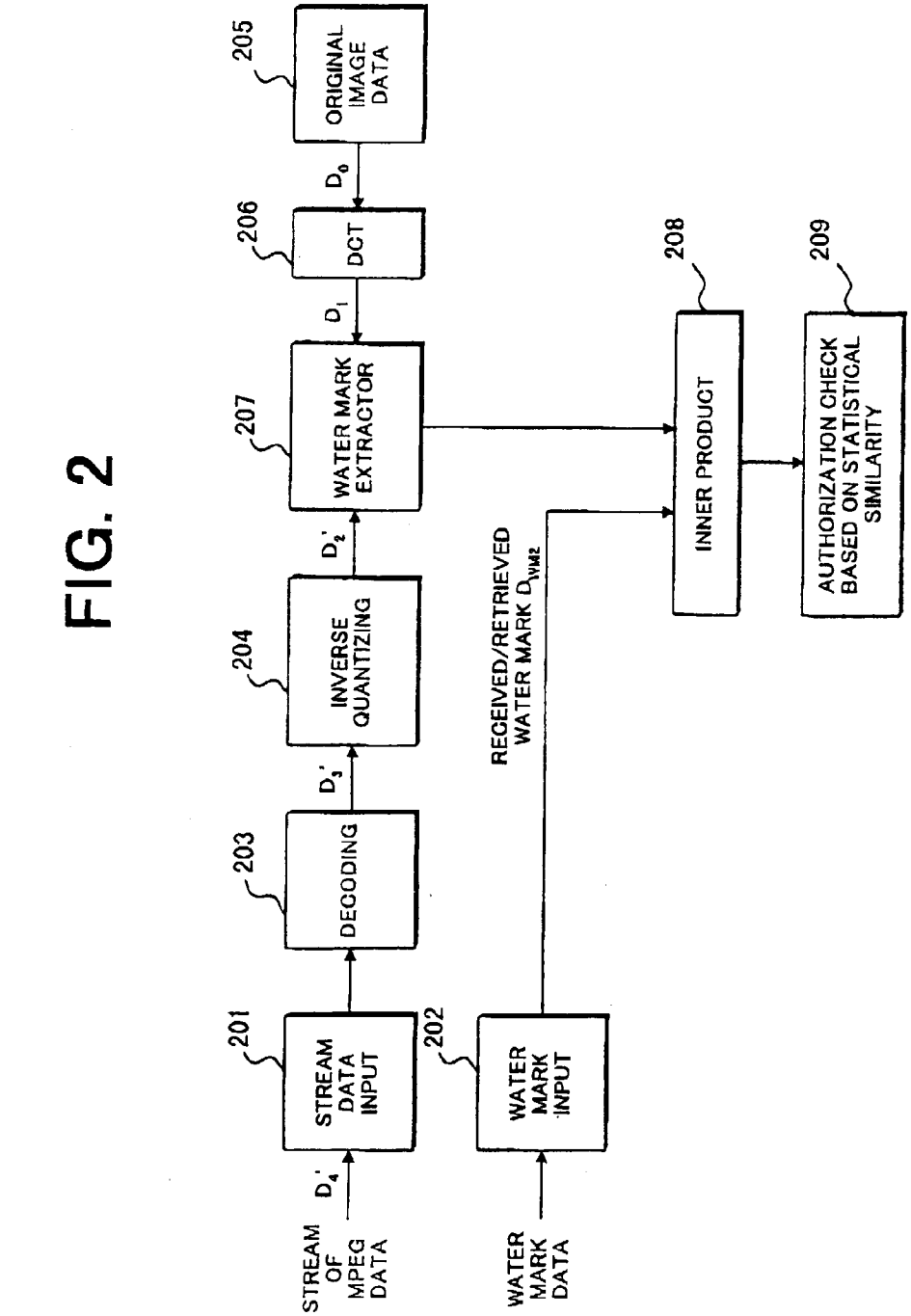

STREAM OF MPEG DATA
D_4'
201
STREAM DATA INPUT
203
DECODING
D_3'
204
INVERSE QUANTIZING
D_2'
207
WATER MARK EXTRACTOR
D_1
206
DCT
D_0
205
ORIGINAL IMAGE DATA
WATER MARK DATA
202
WATER MARK INPUT
REGEIVED/RETRIEVED WATER MARK D_{WM2}
208
INNER PRODUCT
209
AUTHORIZATION CHECK BASED ON STATISTICAL SIMILARITY

FIG. 3

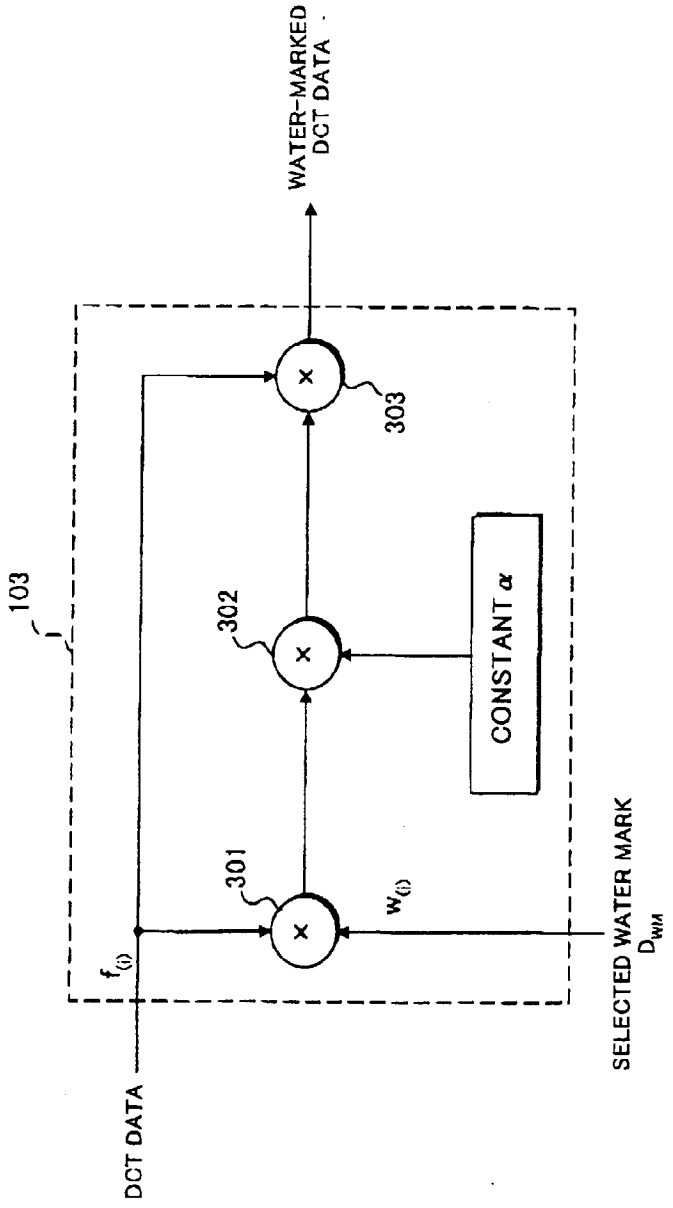

WATER-MARKED DCT DATA
303
302
CONSTANT α
103
301
$w_{(i)}$
$f_{(i)}$
DCT DATA
SELECTED WATER MARK D_{WM}

FIG. 4

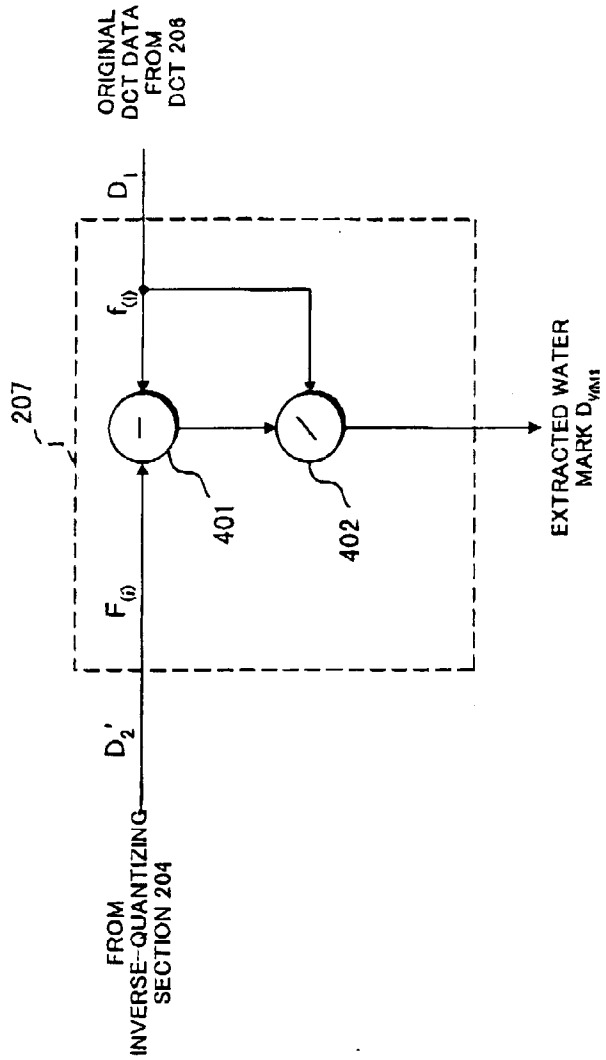

ORIGINAL DCT DATA FROM DCT 206
D_1
$f_{(i)}$
207
401
402
EXTRACTED WATER MARK D_{YM1}
$F_{(i)}$
D_2'
FROM INVERSE-QUANTIZING SECTION 204

FIG. 5

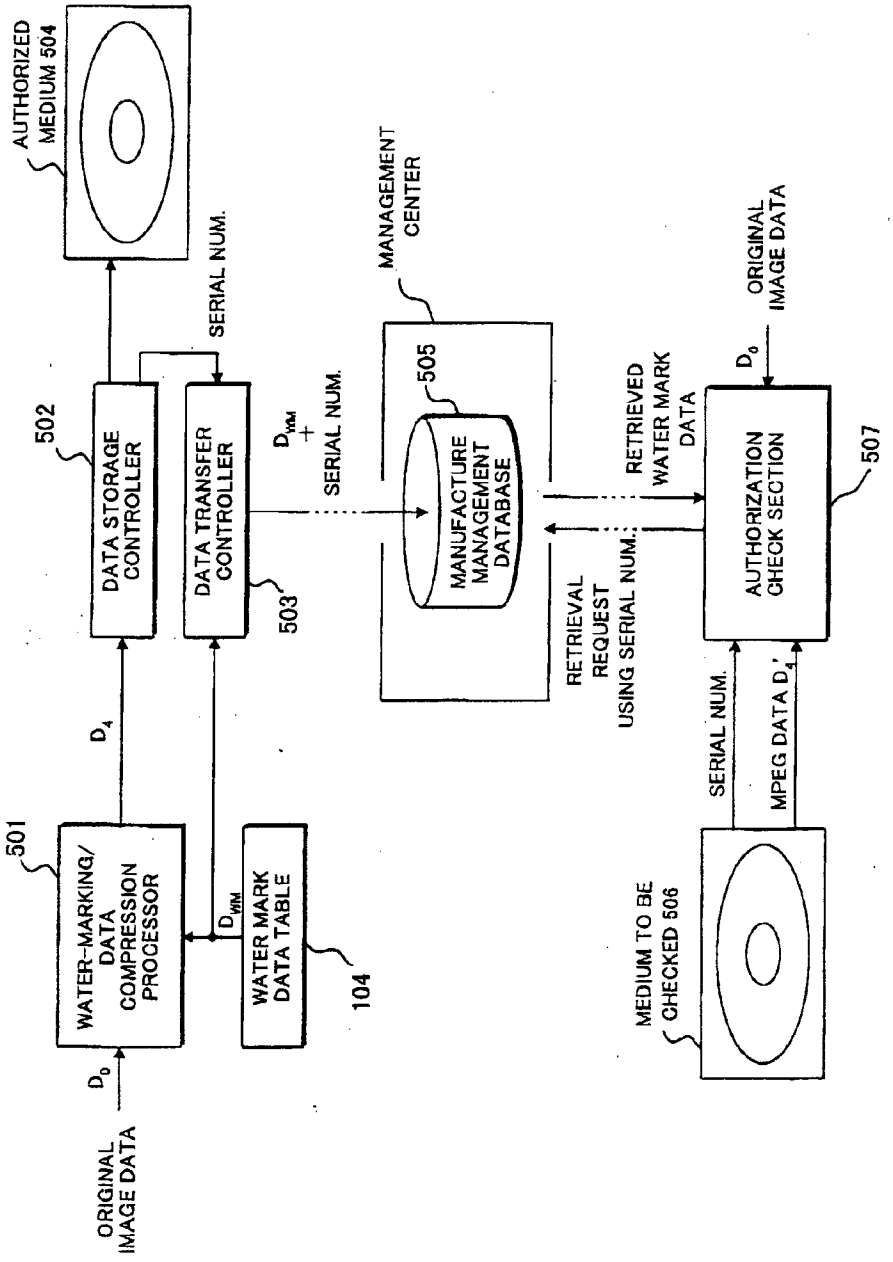

AUTHORIZED MEDIUM 504
SERIAL NUM.
MANAGEMENT CENTER
ORIGINAL IMAGE DATA
502
DATA STORAGE CONTROLLER
DATA TRANSFER CONTROLLER
503
D_{WM} + SERIAL NUM.
505
MANUFACTURE MANAGEMENT DATABASE
RETRIEVED WATER MARK DATA
D_0
AUTHORIZATION CHECK SECTION
507
D_1
501
WATER-MARKING/ DATA COMPRESSION PROCESSOR
D_{WM}
WATER MARK DATA TABLE
104
RETRIEVAL REQUEST USING SERIAL NUM.
D_0
ORIGINAL IMAGE DATA
SERIAL NUM.
MPEG DATA D_1'
MEDIUM TO BE CHECKED 506

FIG. 6

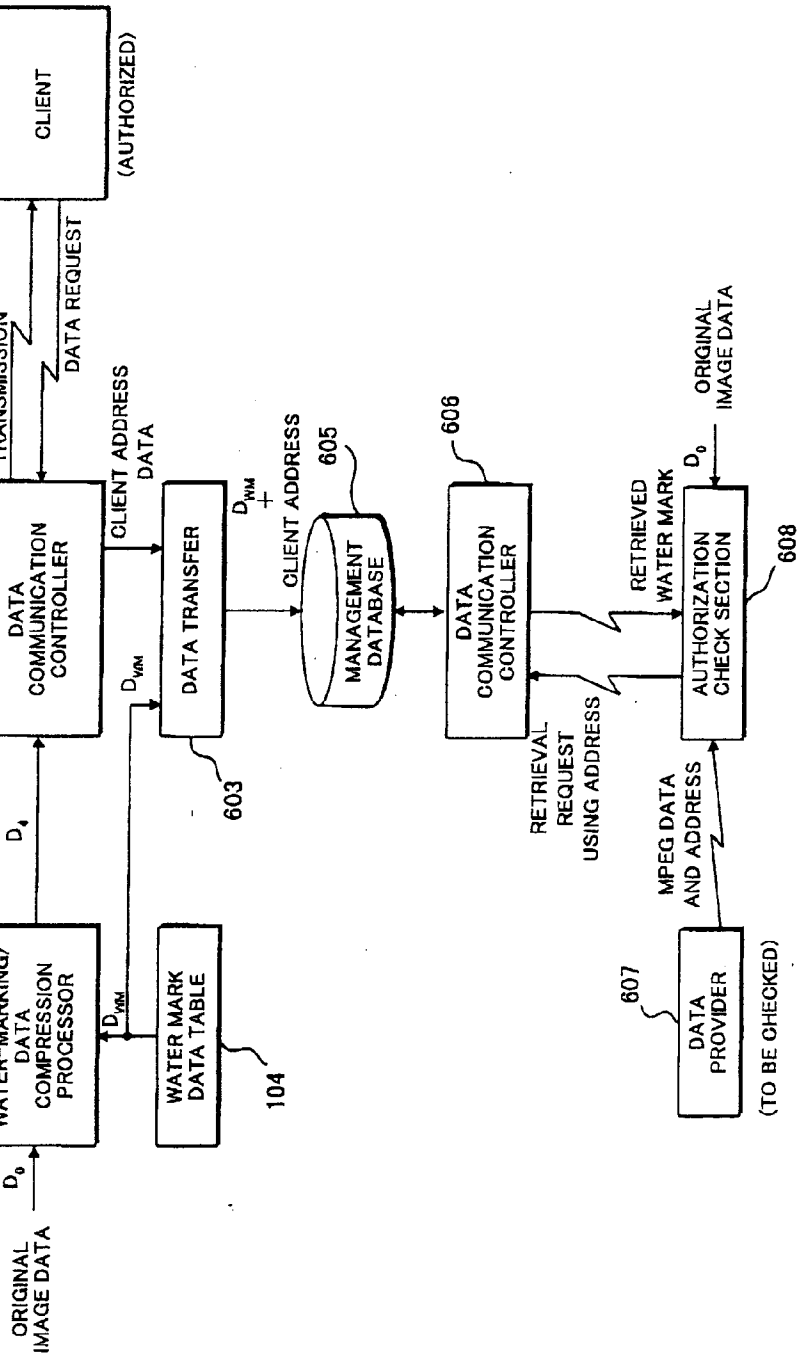

604
CLIENT
(AUTHORIZED)
MPEG DATA TRANSMISSION
DATA REQUEST
602
DATA COMMUNICATION CONTROLLER
CLIENT ADDRESS DATA
DATA TRANSFER
603
CLIENT ADDRESS
605
MANAGEMENT DATABASE
606
DATA COMMUNICATION CONTROLLER
RETRIEVED WATER MARK
ORIGINAL IMAGE DATA
AUTHORIZATION CHECK SECTION
608
RETRIEVAL REQUEST USING ADDRESS
MPEG DATA AND ADDRESS
607
DATA PROVIDER
(TO BE CHECKED)
601
WATER-MARKING/ DATA COMPRESSION PROCESSOR
WATER MARK DATA TABLE
104
ORIGINAL IMAGE DATA

FIG. 7A

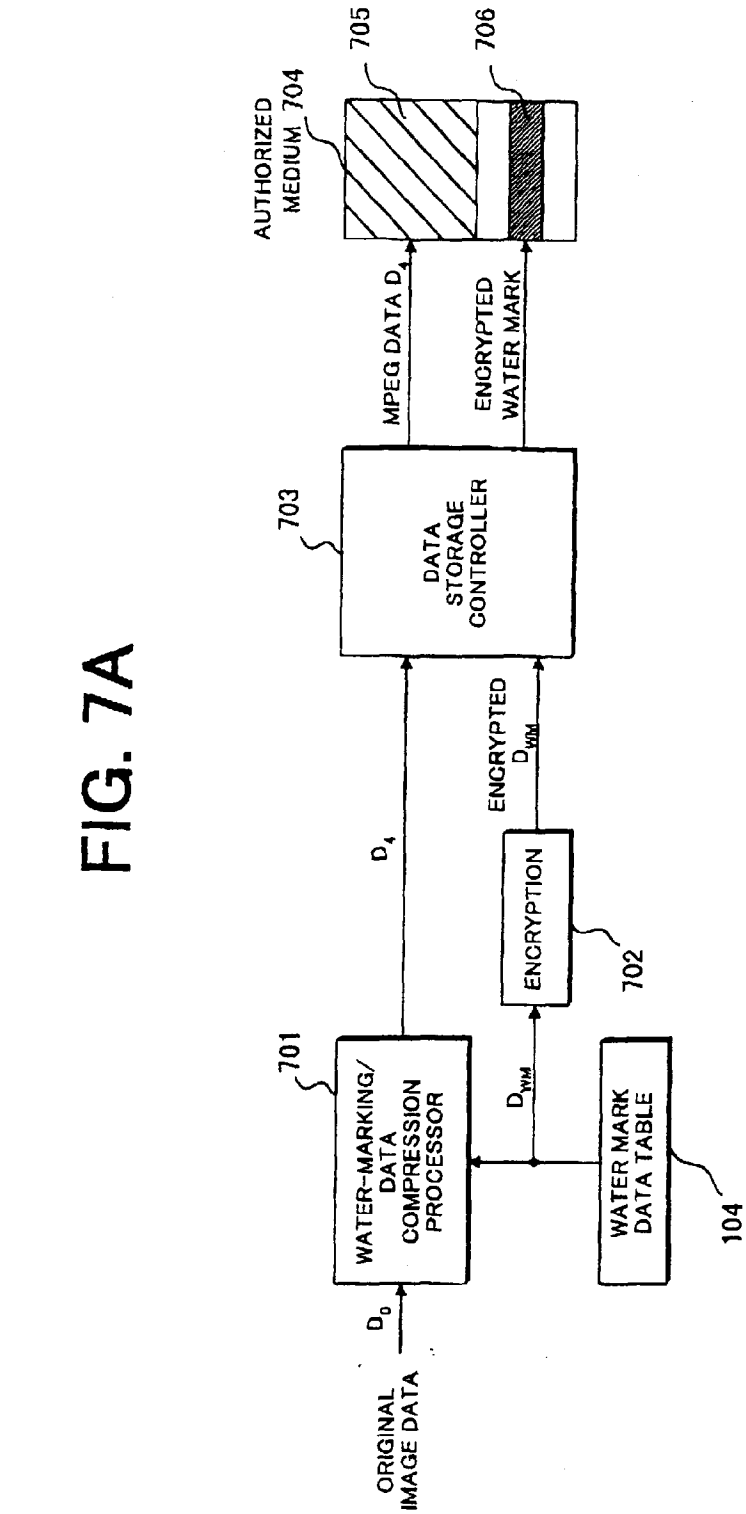
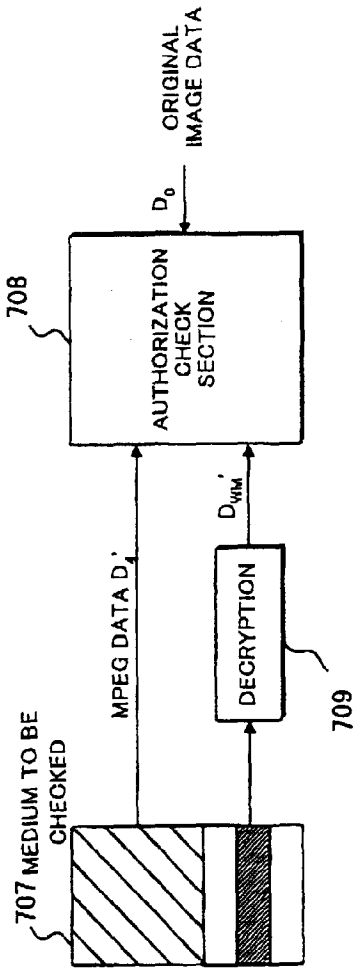

ORIGINAL IMAGE DATA
D_0
WATER-MARKING/ DATA COMPRESSION PROCESSOR
701
WATER MARK DATA TABLE
104
D_{WM}
ENCRYPTION
702
ENCRYPTED D_{WM}
D_4
DATA STORAGE CONTROLLER
703
MPEG DATA D_4
ENCRYPTED WATER MARK
AUTHORIZED MEDIUM 704
705
706

FIG. 7B


ORIGINAL IMAGE DATA
D_0
708
AUTHORIZATION CHECK SECTION
D_{WM}'
MPEG DATA D_1'
DECRYPTION
709
707 MEDIUM TO BE CHECKED